E.S.C.T.S

The Egyptian Cardiothoracic Surgeon

In press

Original Article

Short-term assessment of left ventricular function after coronary artery bypass grafting

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Abstract

Background: The effect of coronary artery bypass grafting on postoperative left ventricular function is still the subject of ongoing studies. The degree of recovery and its duration have not been precisely determined, and the published data are discordant. The objective of this study was to assess the effect of surgical revascularization on left ventricular systolic function.

Methods: We prospectively studied 50 consecutive patients who underwent elective isolated coronary artery bypass grafting in the period from January 2017 to November 2017. All patients had echocardiography preoperatively, pre-discharge, and at 3 and 6 months postoperatively. Left ventricular end-systolic volume, left ventricular end-diastolic volume, stroke volume, and ejection fraction were measured in all patients.

Results: The mean age was 57.22±7.04 years. The mean number of grafts was 2.60±1.02. Improvement in Canadian Cardiovascular Society (CCS) score from (2.72 ± 1.03) preoperatively to [(0.12 ± 0.39), p<0.001] after six months was achieved. Additionally, improvement in the patient New York Heart Association (NYHA) score occurred from (1.70 ± 0.97) preoperatively to [(0.12 ± 0.33), p<0.001] after six months. A significant improvement in left ventricular function occurred as demonstrated by improvement in mean left ventricular ejection fraction from (54.14±9.80) % to [(62.40 ± 4.18) %, p<0.001] at six months. The mean total hospital stay was 5.62±1.51 days. The mean total intensive care unit length of stay was 47.16±25.73 hours. Two patients (4%) had re-exploration for bleeding, and postoperative myocardial infarction occurred in three patients (6%). One patient (2%) had postoperative neurocognitive dysfunction, and 3 patients (6%) had postoperative atrial fibrillation. Two patients (4%) suffered from superficial wound infection. There was no hospital mortality.

Conclusion: Patients undergoing CABG experienced an improvement in left ventricular contractile function at six months postoperatively. Further studies are required to evaluate the changes after 6 months.

KEYWORDS
Coronary artery bypass grafting; Left ventricular function; Surgical revascularization

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Introduction

Long-term outcome of coronary artery bypass grafting (CABG) is excellent compare to coronary stenting, especially in patients with the distal left main disease, extensive multivessel disease and in patients with low ejection fraction and diabetes [1-5]. CABG has been shown to improve survival in the left main disease and in specific subgroups with a multivessel disease [5].

The myocardium may regain contractile function after revascularization if viable myocytes are present [6, 7]. However, the time course of recovery of contractile function after coronary artery bypass grafting is variable and mostly unknown. The studies investigating early postoperative changes have yielded conflicting results. Some have revealed contractile improvement intraoperatively or within the first weeks postoperatively [7, 8], while other studies have detected no change [9, 10] or even deterioration of function [11].

The aim of this study was to assess the effect of coronary artery bypass grafting on left ventricular systolic function.

Patients and Methods:

The study population consisted of 50 patients who were prospectively scheduled for elective isolated CABG between January and November 2017. The participants signed informed consent after receiving full information about the study design. Patients with liver or renal disease, diabetes mellitus, and re-operative CABG were excluded from the study. All patients in this study had a full comprehensive clinical history.

Complete clinical general and cardiac examination was performed for all patients to detect signs of heart failure, arrhythmias, and associated risk factors. Laboratory investigations, plain chest X-ray, 12 lead electrocardiography (ECG) were performed for every patient preoperatively.

Two-dimensional echocardiography was completed within one month of the indexed operation with a SONOS 4500 machine (Philips Technologies, Andover, Massachusetts, USA), equipped with a 2.5-MHz transducer. Preoperative carotid duplex and coronary angiography were performed in all patients. CABG using left internal mammary artery (LIMA) and saphenous vein grafts (SVG) was performed to all patients with a standard incision and closure technique. Fine monofilament polypropylene sutures (8/0 or 7/0) were used for all distal anastomoses. Proximal anastomoses were performed with fine monofilament polypropylene suture (6/0).

Cardiopulmonary bypass was conducted using a membrane oxygenator and a non-pulsatile flow of 2.2-2.5 liters/min/ m2 body surface area. Myocardial protection was through repeated infusions of antegrade warm blood cardioplegia solution every 15:20 minutes containing potassium chloride 0.3 mEq/kg over three minutes as initial dose and then half the dose over 90 seconds every 20 minutes.

Time of aortic cross-clamp, extracorporeal circulation, operative time, number of grafts, inotropic support, and need for intra-aortic balloon pump (IABP) were recorded. Entire intensive care unit (ICU) stay was recorded, and ICU events including dose and duration of inotropic support, use of intra-aortic balloon pump (IABP), perioperative myocardial infarction (MI) diagnosed with new ECG changes plus elevated cardiac enzymes with or without hemodynamic instability, arrhythmias, and postoperative bleeding. The total hospital stay was recorded. Postoperative echocardiography with the estimation of ESV, EDV, SV, and EF was done for all patients within one week after surgery, three months, and after six months postoperatively. The Research Ethics Committee approved the study.

Statistical Analysis

Data were collected, tabulated, and statistically analyzed using an IBM compatible personal computer with SPSS statistical package version 20 (SPSS Inc. released 2011. IBM SPSS statistics for windows, version 20.0, Armonk, NY: IBM Corp.). Quantitative data were summarized as

Table 1: Clinical characteristics and angiographic data. (Continuous data are presented as mean and standard deviation and categorical data as number and percent)

Parameters	N= 50
Age (mean ± SD; years)	57.22 ± 7.04
BMI (mean ± SD; kg/m^2)	30.62 ± 3.81
Male gender [*n* (%)]	44 (88)
Female gender [n (%)]	6 (12)
Previous MI [*n* (%)]	31 (62)
Hypertension [*n* (%)]	25 (50)
Hyperlipidemia	19 (38)
Smoking	
Current smokers	14 (28)
Former smokers	14 (28)
Non smokers	22 (44)
Coronary angiography [*n* (%)]	
One-vessel disease	2 (04)
Two-vessel disease	9 (18)
Multivessel disease	32 (64)
Left main disease	7 (14)
NYHA class [*n* (%)]	
No	5 (10)
I	17 (34)
II	17 (34)
III	10 (20)
IV	1 (02)
CCS class [*n* (%)]	
No	3 (06)
I	2 (04)
II	11 (22)
III	24 (48)
IV	10 (20)
LVEF [*n* (%)]	
≥50	30 (60)
<50	20 (40)
EuroSCORE II [*n* (%)]	
0–1	44 (88)
1–2	5 (10)
2-3	1 (02)

BMI: Body mass index; MI: myocardial infarction; NYHA: New York Heart Association; CCS: Canadian Cardiovascular Society; EuroSCORE II: European System for Cardiac Operative Risk Evaluation; LVEF: left ventricular ejection fraction.

mean ± standard deviation (SD), while qualitative data were described using number and percent. The Kolmogorov-Smirnov test was used to verify the normality of distribution. ANOVA with repeated measures was used for normally distributed quantitative variables to compare between more than two periods or stages, and Post Hoc test (Bonferroni adjusted) for pairwise comparisons. Friedman test was used for abnormally distributed quantitative variables to compare between more than two periods or stages and Post Hoc test (Dunn-Bonferroni) for pairwise comparisons. A p-value of less than 0.05 was always used to indicate significance.

Results

This study included 50 (44 male and 6 female) patients who underwent isolated CABG. Their mean age was 57.22±7.04 years (range between 35 and 69 years). Preoperative echocardiographic data showed mean end-systolic volume index (ESVI) (27.63±9.66 ml/m2), mean end-diastolic volume index (EDVI) (60.26±11.17 ml/m2), mean stroke volume (SV) (64.86±11.95 ml), and mean ejection fraction (EF) (54.14±9.80) %. Baseline clinical characteristics and angiographic data of the study population are presented in Table 1.

The mean total bypass time was 90.56±32.22 minutes. Inotropic support was used in 28 patients (56%) with a mean duration of 14.32±18.72 hours. Of those patients who required inotropic support, there were 14 patients admitted to surgery with low preoperative EF (<50%), and 6 patients had incomplete revascularization due to the surgeon's inability to graft tiny and diffusely diseased coronary arteries. Intra-aortic balloon pump was used in one patient only (2%) who had a low preoperative EF (38%) and was incompletely revascularized (Table 2).

Table 2: Operative data (Continuous data are presented as mean and standard deviation and categorical data as number and percent)

Operative data	No. = 50
Mean cross clamp time (min)	51.80±19.90
Mean total bypass time (min)	90.56±32.22
Mean total operative time (min)	261.0±261.0
Total number of grafts	133(2.60±1.02)
DC shocks	4(8%)
Incomplete revascularization	8(16%)
IABP	1(2%)
Inotropic support	28(56%)

IABP: intra-aortic balloon pump

Table 3: Postoperative data. (Continuous data are presented as mean and standard deviation and categorical data as number and percent)

Postoperative Data	
Total ICU stay (hr)	47.16±25.73
Total hospital stay (days)	5.62±1.51
Ventilation hours (hr)	6.56±3.98
Inotropic support n (%)	28 (56%)
Inotropic support duration (hr)	14.32±18.17
Peri-operative MI n (%)	3 (6%)
Reopening for bleeding	2 (4%)
Neurocognitive dysfunction	1 (2%)
Atrial fibrillation	3 (6%)
Superficial wound infection	2 (4%)
MI: myocardial infarction	

The mean ICU stay was 47.16±25.73 hours. No mortality was recorded during the study period. Postoperative myocardial infarction occurred in 3 patients (6%). Of those who developed postoperative MI, one patient was admitted with low preoperative EF (38%), incompletely revascularized, and required insertion of IABP. The second patient needed LAD endarterectomy and was completely revascularized with five grafts and prolonged cross-clamp time (125 minutes) and total bypass time (205 minutes). The third patient developed MI with no apparent reason to us but may be due to venous graft occlusion or native coronary artery diffuse disease. Postoperative atrial fibrillation recorded in three patients (6%) of whom 2 patients had a low preoperative EF, and the three patients were nonsmokers. One case recovered with agitation. Two cases were reopened for bleeding postoperatively. Two cases had a superficial wound infection (Table 3).

Improvement of preoperative patient symptoms was observed postoperatively with improvement in Canadian Cardiovascular Society (CCS) score from (2.72 ± 1.03) preoperatively to [(0.16 ± 0.42), p<0.0001] after three months, and then to [(0.12 ± 0.39), p<0.001] after six months (Table 4).

Postoperative echocardiography (pre-hospital discharge) showed mean ESVI [(26.67 ± 6.49 ml/m2), p=1.000], mean EDVI [(59.11 ± 9.26 ml/m2), p=1.000], mean SV [(64.60 ± 8.81 ml.), p=1.000], and mean EF [(54.64 ± 5.76) %, p=1.000]. Echocardiography 3 months after operation showed mean ESVI [(23.01 ± 4.57 ml/m2), p<.001], mean EDVI [(56.78 ± 7.84 ml/m2), p=0.137], mean SV [(69.08 ± 6.97 ml), p=0.023], and mean EF [(60.12 ± 4.64) %, p<0.001]. Echocardiography after 6 months showed mean ESVI [(21.07 ± 4.10 ml/m2), p<0.001], mean EDVI [(56.76 ± 6.77 ml/m2), p=0.009], mean SV [(71.74 ± 5.97 ml), p<0.001], and mean EF [(62.40 ± 4.18) %, p<0.001]. Preoperative and postoperative echo-cardiographic measurements in the study population as a whole are presented in (Table 5).

Discussion

Studies assessing the changes in left ventricular systolic function after CABG are scarce. We evaluated the pre- and postoperative echocardiography in patients undergoing CABG with normal or reduced preoperative ejection fraction. In the present study, there was a significant difference in NYHA functional classification as it is decreased from (1.70±0.97) preoperatively to (0.12±0.33) at six months. Eleven (22%) patients were complaining of dyspnea NYHA III/IV preoperatively. After CABG, improvement in heart failure symptoms was observed in the study population, with only 6 (12%) patients had dyspnea (NYHA I). These results come in agreement with others [12, 13] who found a correlation between the clinical and echocardiographic, and the extent of preoperative myocardial viability. Furthermore, Marwick and collaborators [14] found an association between exercise capacity and degree of jeopardized tissue diagnosed with positron emission tomography.

Table 4: Changes in CCS and NYHA (Data are presented as mean and standard deviation)

Variables	PRE	After 3 months	After 6 months	p-value
CCS	2.72±1.0	0.16±0.42	0.12±0.39	<0.001
NYHA	1.70±0.9	0.38±0.60	0.12±0.33	<0.001

NYHA: New York Heart Association; CCS: Canadian Cardiovascular Society

Table 5: Echocardiographic measurements before and after CABG. (Data are presented as mean and standard deviation.)

Variables	All patients (n=50)				p-value
	Pre-CABG	One-week Post-CABG	After 3 months	After 6 months	
LVEF (%)	54.14±9.80	54.64±5.76	60.12±4.64	62.40±4.18	<0.001
ESVI (ml/m²)	27.63±9.66	26.67±6.49	23.01±4.57	21.07±4.10	<0.001
EDVI (ml/m²)	60.26±11.17	59.11±9.26	56.78±7.84	56.76±6.77	0.009
SV (ml)	64.86±11. 95	64.60±8.81	69.08±6.97	71.74±5.97	<0.001

LVEF: left ventricular ejection fraction; ESVI: end-systolic volume index: EDVI: end-diastolic volume index; SV: stroke volume.

Several studies [15, 16] showed that successful revascularization of viable myocardial tissue with CABG might restore myocardial perfusion, improve left ventricular function, and alleviate anginal complaints. In the present study, the Canadian Cardiovascular Society (CCS) classification of angina improved significantly from (2.72 ± 1.03) to (0.12 ± 0.39) at six months. The results were in agreement with Peric and colleagues [17] that showed that the CCS angina class improved after CABG. Additionally, we confirmed previous findings in the literature [18, 19] that after CABG, the vast majority of the patients have less or no angina. The question of whether revascularization can alleviate symptoms in these patients, which are usually their primary functional limitation, remains a paramount concern both for patients and surgeons. We observed a marked improvement of anginal symptoms and reduction of anti-anginal medications postoperatively.

From a hemodynamic point of view, a significant improvement in overall left ventricular systolic function occurred in the whole cohort of the patients as demonstrated by decrease in mean ESVI from (27.63 ± 9.66 ml/m2) preoperatively to (23.01 ± 4.57 ml/m2) at three months, and then to (21.07 ± 4.10 ml/m2) at six months. Moreover, a decrease in mean EDVI from (60.26 ± 11.17 ml/m2) preoperatively to (56.78 ± 7.84 ml/m2) occurred at three months postoperatively, and then to (56.76 ± 6.77 ml/ m2) at six months postoperatively. Increase in mean SV from (64.86 ± 11.95 ml) preoperatively to (69.08 ± 6.97 ml) occurred at three months and then to (71.74 ± 5.97 ml) at six months postoperatively. The mean EF significantly increased from (54.14 ± 9.8) % preoperatively to (60.12±4.64) % at three months, and then to (62.40±4.18) % at six months. In our cohort, the maximum improvement in LV contractility parameters was observed after 6 months. A similar time of systolic function recovery after revascularization was noted by others [20-21]. On the other hand, Rizzello and colleagues [22] observed the improvement in NYHA and CCS class after 9 to 12 months from the intervention.

In view of these data, Bax [6] emphasized that the choice of the optimum contractility assessment period after CABG remains unclear. Literature data suggested that cardiomyocyte function recovery may be expected between 6 and 12 months after the intervention [12, 23], or sometimes after a more extended period of up to 4 years [24]. In essence, the functional recovery of the impaired ventricular function depends on the restoration of effective contractile myocardium though it may take a different time period depending on some crucial factors, such as the duration of hypoperfusion, degree of ventricular remodeling, etc. As long as there is enough viable myocardium in the impaired ventricle, there is the possibility of the improvement or recovery in systolic function with the restoration of blood supply.

An increase in left ventricular ejection fraction after coronary revascularization is generally thought to be due to hibernation [25, 26], and stunning has also been suggested as an explanation [27]. We observed significantly improved LVEF values in 58% of all our patients. This suggests a mixture of hibernation and chronic or repetitive stunning. This should be seen in the light of the fact that 60% of all patients had normal LVEF before surgery. The mechanism and underlying pathophysiology are not evident, but the simple clinical consequence is that in a patient population like the present one— patients referred for CABG mainly because of angina combined with a lack of technical possibility for PCI and with a rather low European System for Cardiac Operative Risk Evaluation (EuroSCORE II), chances of improved left ventricular function are significant and independent of the kind of perfusion defects. Patients with non-viable myocardium will show little or no improvement of LV function after the restoration of the blood flow. In patients with borderline perfusion defects, revascularization may lead to partial improvement, and the viability study will determine the fate of the irreversible part of the defect.

Study limitations

There are several limitations to our study. There are no preoperative viability studies to all patients; however, routine viability studies were not indicated in all patients without echocardiographic data suggestive of non-viable myocardium. Our sample size is limited; however, we were able to detect the improvement of left ventricular function in our patients. Finally, coronary angiography was not repeated postoperatively to verify graft patency; routine coronary angiography is not the standard of care.

Conclusion

Patients undergoing CABG experience an improvement in left ventricular contractile function within six months of the operation as detected with echocardiography. Further improvement in left ventricular contractile function may occur after six months post CABG that needs further studies.

Conflict of interest: Authors declare no conflict of interest.

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